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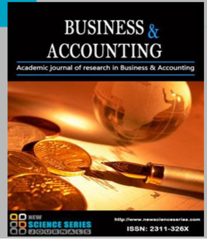

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Evaluating a Green Supplier Selection Problem Considering Payment Methods Using TOPSIS Algorithm: A Case Study

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Abstract

Regarding growing awareness of environmental protection and continuous development in companies, green raw materials have in recent years become an important issue for organizations and suppliers in the long term. As the green aspects play an important role in organizations to make a decision, this paper presents a green supplier selection (GSS) problem including 7 criteria with 18 sub criteria. The aim of this paper is to find the best supplier among available suppliers considering several quantitative and qualitative criteria, namely the cost, the quality, the delivery, the technology capability, the environmental competency, the payment methods, and the availability of materials. Since the proposed model belongs to multi criteria decision making (MCDM) problems, this paper employs an MADM (multi-attribute decision making) method, namely TOPSIS (the technique for order of preference by similarity to ideal solution) to solve it. The SAW (simple additive weighting) is used to validate and verified the employed algorithm as well. A case study as a numerical example is employed to show the performance of the proposed strategy. Finally, the conclusion and future research are presented.

Keywords: *Green Supplier Selection, Multi-Criteria Decision-Making (MCDM), Payment Methods, TOPSIS, SAW.*

Introduction

In companies and industries, the cost of raw materials is the considerable portion of a final cost of an item; thus, the selection of suitable suppliers greatly reduces costs. The supplier selection is a multi-criterion problem which includes both qualitative and quantitative criteria. Raw materials used in manufacturing products may cause environmental problems. Considering the growing awareness of environmental aspects, vendors try to buy items from suppliers who satisfy the required qualitative and quantitative criteria. The main aim of the green supplier selection (GSS) problem is to select the best supplier among several suppliers.

To consider the supplier selection literature, there are several papers that conducted a review of supplier selection problems, for example, Weber et al. (1991) considered the criteria and analytical methods from 1966 to 1991. Next, De Boer et al. (2001) made a good review of the decision methods. Afterwards, Ho et al. (2010) considered a review of the supplier selection problems from 2000 to 2008. Chai et al. (2013) made a good review of the decision maker (DM) techniques from 2008 to 2012. In a similar manner, in the green area, Govindan et al. (2013) and Igarashi et al. (2013) considered a review of the GSS problems from 1991 to 2011. Consequently, this article considered the supplier selection literature after these mentioned reviews. Dou et al. (2014) evaluated a GSS problem to increase suppliers' performance using a grey analytical network process ANP-based.

In this paper, a green supplier selection (GSS) problem is evaluated in which 7 criteria with 18 sub criteria are considered. The purpose of this article is to select the best supplier among available suppliers regarding several quantitative and qualitative criteria which are the quality, the cost, the technology capability, the delivery, the payment methods, the environmental competency and the availability of materials. As the presented model is a multi-criteria decision making (MCDM) problem, this article uses two MADM (multi-attribute decision-making) methods to solve it. TOPSIS (the technique for order of preference by similarity to ideal solution) and SAW (simple additive weighting) evaluate the proposed model to find the best supplier. This study also intends to solve the green supplier selection (GSS) problem in a case study. The main contribution of this paper is to consider two criteria namely the availability of materials and the payment methods. The remainder of this article is organized as follows. Section 2 illustrates the proposed green supplier selection model. The proposed method is explained in Section 3. Section 4 demonstrates a case study. The concluding remarks are finally made in Section 5.

The proposed green supplier selection model

This paper considers several criteria relevant to the proposed problem. The proposed problem consists of 7 criteria with 18 sub-criteria in which belongs to MCDM problems. Table 1 shows the criteria investigated in this paper. It is assumed that there is no constraint on the model. Next Section presents two of MADM methods namely TOPSIS and SAW to solve the proposed model to find the best supplier.

The solution algorithms

Since the presented model is a MCDM problem, this paper employs an MADM approach, namely TOPSIS, to evaluate the suppliers. In order to validate and verified the proposed algorithm, the SAW (simple additive weighting) (Sadeghi et al. 2012, Sadeghi et al. 2014) is used as well. TOPSIS (The Technique for Order Preference by Similarity to Ideal Solution) based upon the concept that the chosen alternative should have the shortest distance from the ideal solution and the farthest from the negative-ideal solution, which the following steps describe it (Hwang and Yoon 1981).

Step 1. Construct the normalized decision matrix:

$$n_{ij} = \frac{r_{ij}}{\sqrt[2]{\sum_{i=1}^{m} r_{ij}^{2}}} \tag{1}$$

Step 2. Construct the weighted normalized decision matrix:

$W = \{w_1, w_2, w_3, \ldots, w_n\} \approx$ (From the decision maker); $\sum_{i=1}^{n} w_j = 1$

Table 1. The criteria used in the proposed problem (Kannan et al. 2013)

Criteria	Sub criteria	Definition
1. Payment Methods	1.1. Cash (PCA)	Is a way of payment.
	1.2. Check (PCH)	Is a way of payment.
	1.3. Credit (PCR)	Is a way of payment.
2. Quality	2.1. Quality assurance (QA)	Is a way of preventing mistakes or defects in manufactured products.
	2.2. Rejection ratio (QR)	Number of rejected incoming material
3. Environmental Competency	3.1. Pollution production (EP)	Average volume of air emission pollutant, waste water, solid wastes and harmful materials releases per day during measurement period.
	3.2. Resource consumption (ER)	Resource consumption in terms of raw material, energy and water during the measurement period.
	3.3. Environmental management system (EM)	Environmental certifications like ISO 14000, environmental policies, planning, checking and control of environmental activities.
	3.4. Eco-design (ED)	Design of products for reduced consumption of material/Energy, design of products for reuse, recycle, recovery of material.
4. Available	4.1. Supplier as a vendor (AV)	When supplier is as a vendor, he is supplied by an outer supplier.
	4.2. Supplier as a manufacturer (AM)	Supplier produces himself items.
5. Cost	5.1. Product cost (CP)	The sum of all costs associated with the production of a specific quantity of a good or service.
	5.2. Logistics cost (CL)	Sum of unit variable and allocated fixed transportation costs.
6. Technology Capability	6.1. Technology level (TL)	Technology development of the supplier to meet current and future demand of the firm.
	6.2. Capability of R&D (TR)	Capability of R&D of the supplier to meet current and future demand of the firm.
	6.3. Capability of design (TD)	Capability of new product design of the supplier to meet current and future demand of the firm Environmental.
7. Delivery	7.1. Lead time (DL)	Time between placement and arrival of an order.
	7.2. Order fulfillment rate (DR)	Compliance with the predetermined order quantities Technology.

$$V = N_D.W = \begin{vmatrix} V_{11} \cdots & V_{1j} & V_{1n} \\ \cdots & \cdots & \cdots \\ V_{m1} & V_{mj} & V_{mn} \end{vmatrix} \tag{2}$$

Step 3. Determine ideal and negative- ideal solutions:

Let the two artificial alternatives A^+ and A^- be defined as

$$A^+ = \{(\max V_{ij} \mid j \in J), (\min V_{ij} \mid j \in J^{'}) \mid i = 1, 2, \ldots, m\};$$
$$A^+ = \{V_1^{\,+}, V_2^{\,+}, \ldots, V_j^{\,+}, \ldots, V_n^{\,+}\}; \tag{3}$$

$$A^{-} = \{(\min V_{ij} \mid j \in J), (\max V_{ij} \mid j \in J^{'}) \mid i = 1, 2, \ldots, m\};$$
$$A^{-} = \{V_1^{-}, V_2^{-}, \ldots, V_j^{-}, \ldots, V_n^{-}\}; \tag{4}$$

Where

$$J = \{ j = 1, 2, \ldots, n \mid j \text{ associated with benefit criteria}\};$$
$$J^{'} = \{ j = 1, 2, \ldots, n \mid j \text{ associated with cost criteria}\}; \tag{5}$$

Then it is certain that the two created alternatives A^{+} and A^{-} indicate the most preferable alternative (ideal solution) and the least preferable alternative (negative-ideal solution) respectively.

Step 4. Calculate the separation measure:

The separation between each alternative can be measured by the n-dimensional Euclidean distance. The separation of each alternative from the ideal one is then given by

$$d_i^{+} = (\sum (V_{ij} - V_j^{+})^2)^{0.5}; \qquad i = 1, 2, \ldots, m \tag{6}$$

Similarly, the separation from the negative-ideal one is given by

$$d_i^{-} = (\sum (V_{ij} - V_j^{-})^2)^{0.5}; \qquad i = 1, 2, \ldots, m \tag{7}$$

Step 5. Calculate the relative closeness to the ideal solution:

The relative closeness of A_i with respect to A^{+} is defined as

$$cl_{i+} = \frac{d_{i-}}{(d_{i+} + d_{i-})}; \qquad 0 \leq cl_{i+} \leq 1 \quad ; \quad i = 1, 2, \ldots, m \tag{8}$$

It is clear that $cl_{i+} = 1$ if $A_i = A^{+}$ and $cl_{i+} = 0$ if $A_i = A^{-}$. An alternative A_i is closer to A^{+} as cl_{i+} approaches to 1.

Step 6. Rank the preference order

A set of alternatives can now be preference ranked according to the descending order of cl_{i+} (Hwang and Yoon 1981).

The numerical example: case study

In order to describe the sufficiency of the presented strategy, a case study as a numerical example in a manufacturing company is used. In this case study, needed data about criteria and their weights are obtained from the experts and the different sections of company. According to Table 1, the obtained information shown in Table 2 includes quantitative and qualitative values. The criteria weights are shown in Table 3 as well.

While Table 4 shows linguistic variables for pair-wise comparisons of each criterion, regarding the mentioned solution algorithm in the previous Section, the following steps are used to solve the proposed problem.

Table 2. Data

Supplier *i th*	Criteria																
	Cost		Quality		Delivery		Technology Capability			Environmental Competency				Payment Methods			Available	
	CP	CL	QA	QR	DL	DR	TL	TR	TD	EP	ER	EM	ED	PCA	PCH	PCR	AV	AM
i=1	121	34	G	3.7	15	90	G	G	MP	P	VG	VP	M	1	0	0	0	0
i=2	144	32	MG	3.1	20	96	M	VG	P	MP	G	VP	G	1	1	0	0	0
i=3	91	23	VG	6.6	30	93	VG	VP	G	G	M	G	VG	1	0	1	1	0
i=4	148	34	VP	4.1	19	100	MG	G	P	M	M	MG	M	1	0	1	1	0
i=5	111	30	G	6.8	21	95	MG	MP	MG	P	VG	P	P	1	1	0	1	1

Abbreviation used in Table 2:

CP: Product Cost; CL: Logistics Cost; QA: Quality Assurance; QR: Rejection Ratio (%); DL: Lead Time; DR: Order Fulfillment Rate (%); TL: Technology Level; TR: Capability of R&D; TD: Capability of Design; EP: Pollution Production; ER: Resource Consumption; EM: Environmental Management System; ED: Eco-Design; PCA: Cash; PCH: Check; PCR: Credit; AV: Supplier as a Vendor; AM: Supplier as a Manufacturer.

Table 3. Criteria weights

Supplier i^{th}	CP	CL	QA	QR	DL	DR	TL	TR	TD	EP	ER	EM	ED	PCA	PCH	PCR	AV	AM
Weight	0.2	0.1	0.2	0	0.1	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0.1

Table 4: Linguistic variables for pair-wise comparisons of each criterion.

1	Very Poor (VP)
2	Poor (P)
3	Medium Poor (MP)
4	Medium (M)
5	Medium Good (MG)
6	Good (G)
7	Very Good (VG)

Step 1. Construct the normalized decision matrix:

Table 5: The normalized decision matrix

	Criteria																	
	Cost		Quality		Delivery		Technology Capability			Environmental Competency				Payment Methods			Available	
benefit or cost	-	-	+	+	-	+	+	+	+	-	-	+	+	-	+	+	-	+
Weight	0.2	0.1	0.2	0	0.1	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0.1
Supplier i^{th}	CP	CL	QA	QR	DL	DR	TL	TR	TD	EP	ER	EM	ED	PCA	PCH	PCR	AV	AM
i=1	0.18	0.00	0.86	0.55	0.50	0.90	0.86	0.86	0.50	0.67	0.00	0.17	0.57	0.00	0.00	0.00	1.00	0.00
i=2	0.03	0.07	0.71	0.46	0.33	0.96	0.57	1.00	0.33	0.50	0.14	0.17	0.86	0.00	1.00	0.00	1.00	0.00
i=3	0.39	0.33	1.00	0.98	0.00	0.93	1.00	0.14	1.00	0.00	0.43	1.00	1.00	0.00	0.00	1.00	0.00	0.00
i=4	0.00	0.00	0.14	0.60	0.37	1.00	0.71	0.86	0.33	0.33	0.43	0.83	0.57	0.00	0.00	1.00	0.00	0.00
i=5	0.25	0.12	0.86	1.00	0.30	0.95	0.71	0.43	0.83	0.67	0.00	0.33	0.29	0.00	1.00	0.00	0.00	1.00

Note that all attributes except CP, CL, DL, EP, ER, PCA, and AV are the benefit criteria.

Step 2. Construct the weighted normalized decision matrix (Table 6)

Step 3. Determine ideal and negative ideal solutions:

$$A^{+} = \{(\underset{i}{MAX}\ V_{ij} \mid j \in J), (\underset{i}{MIN}\ V_{ij} \mid j \in J')\mid i = 1, 2, \ldots, m\}; \tag{9}$$

$$\begin{aligned} A^{+} = \{&\underset{i}{MIN}\ V_{i1}, \underset{i}{MIN}\ V_{i2}, \underset{i}{MAX}\ V_{i3}, \underset{i}{MAX}\ V_{i4}, \underset{i}{MIN}\ V_{i5}, \underset{i}{MAX}\ V_{i6}, \underset{i}{MAX}\ V_{i7}, \underset{i}{MAX}\ V_{i8}, \\ &\underset{i}{MAX}\ V_{i9}, \underset{i}{MIN}\ V_{i10}, \underset{i}{MIN}\ V_{i11}, \underset{i}{MAX}\ V_{i12}, \underset{i}{MAX}\ V_{i13}, \underset{i}{MIN}\ V_{i14}, \underset{i}{MAX}\ V_{i15}, \underset{i}{MAX}\ V_{i16}, \\ &\underset{i}{MIN}\ V_{i17}, \underset{i}{MAX}\ V_{i18}\}; \end{aligned} \tag{10}$$

$$A_j^{+} = \{0.00,\ 0.00,\ 0.15,\ 0.03,\ 0.00,\ 0.02,\ 0.03,\ 0.02,\ 0.04,\ 0.00,\ 0.00,\ 0.02,\ 0.01,\ 0.00,\ 0.03,\ 0.06,\ 0.00,\ 0.10\}$$

$$A^{-} = \{(\underset{i}{MIN}\ V_{ij} \mid j \in J), (\underset{i}{MAX}\ V_{ij} \mid j \in J')\mid i = 1, 2, \ldots, m\}; \tag{11}$$

$$A^{-} = \{\underset{i}{MAX}\, V_{i1},\ \underset{i}{MAX}\, V_{i2}, \underset{i}{MIN}\, V_{i3}, \underset{i}{MIN}\, V_{i4}, \underset{i}{MAX}\, V_{i5}, \underset{i}{MIN}\, V_{i6}, \underset{i}{MIN}\, V_{i7}, \underset{i}{MIN}\, V_{i8},$$
$$\underset{i}{MIN}\, V_{i9}, \underset{i}{MAX}\, V_{i10}, \underset{i}{MAX}\, V_{i11}, \underset{i}{MIN}\, V_{i12}, \underset{i}{MIN}\, V_{i13}, \underset{i}{MAX}\, V_{i14}, \underset{i}{MIN}\, V_{i15}, \quad (12)$$
$$\underset{i}{MIN}\, V_{i16,}\, \underset{i}{MAX}\, V_{i17}, \underset{i}{MIN}\, V_{i18}\};$$

$$A_j^{-} = \{0.09,\ 0.02,\ 0.02,\ 0.01,\ 0.05,\ 0.02,\ 0.02,\ 0.00,\ 0.01,\ 0.01,\ 0.01,\ 0.00,\ 0.00,\ 0.00,\ 0.00,\ 0.00,\ 0.05,\ 0.00\}$$

Table 6: The weighted normalized decision matrix

	Criteria																	
	Cost		Quality		Delivery		Technology Capability			Environmental Competency				Payment Methods			Available	
	C 1		C 2		C 3		C 4			C 5				C 6			C 7	
benefit or cost	-	-	+	+	-	+	+	+	+	-	-	+	+	-	+	+	-	+
Weight	0.2	0.1	0.2	0	0.1	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0.1
Supplier i^{th}	CP	CL	QA	QR	DL	DR	TL	TR	TD	EP	ER	EM	ED	PCA	PCH	PCR	AV	AM
i=1	0.04	0.00	0.13	0.02	0.05	0.02	0.03	0.02	0.02	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.05	0.00
i=2	0.01	0.00	0.11	0.01	0.03	0.02	0.02	0.02	0.01	0.01	0.00	0.00	0.01	0.00	0.03	0.00	0.05	0.00
i=3	0.09	0.02	0.15	0.03	0.00	0.02	0.03	0.00	0.04	0.00	0.01	0.02	0.01	0.00	0.00	0.06	0.00	0.00
i=4	0.00	0.00	0.02	0.02	0.04	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.06	0.00	0.00
i=5	0.06	0.01	0.13	0.03	0.03	0.02	0.02	0.01	0.03	0.01	0.00	0.01	0.00	0.00	0.03	0.00	0.00	0.10

Step 4. Calculate the separation measure:

$$D_1^{+} = 0.14,\ \ D_2^{+} = 0.14,\ \ D_3^{+} = 0.14,\ \ D_4^{+} = 0.17,\ \ D_5^{+} = 0.09$$

$$D_1^{-} = 0.12,\ \ D_2^{-} = 0.12,\ \ D_3^{-} = 0.16,\ \ D_4^{-} = 0.12,\ \ D_5^{-} = 0.16$$

Step 5. Calculate the relative closeness to the ideal solution

$$CL_1^{+} = 0.46,\ \ CL_2^{+} = 0.47,\ \ CL_3^{+} = 0.53,\ \ CL_4^{+} = 0.42,\ \ CL_5^{+} = 0.65$$

$$CL_1^{+} = A_1,\ \ CL_2^{+} = A_2,\ \ CL_3^{+} = A_3,\ \ CL_4^{+} = A_4,\ \ CL_5^{+} = A_5$$

Step 6. Rank the preference order

According to the descending order of C_i^{*}, the preference order is: $A_5 > A_3 > A_2 > A_1 > A_4$ that is the 5th supplier is the best among the available supplier. Also, the SAW method as a validator algorithm presents 5th supplier as the best supplier, which the solution proposed by the SAW is: $A_5 > A_3 > A_1 > A_2 > A_4$.

Conclusion

This paper has presented a multi criteria decision making (MCDM) problem including several quantitative and qualitative criteria. There were 7 criteria and 18 sub-criteria in the proposed green supplier selection (GSS) problem, which are the availability of materials, the technology capability, the quality, the environmental competency, the cost, and the payment methods, and the delivery. The aim of this research was to select the best supplier among the available suppliers considering the criteria. Since the presented model belonged to MCDM problems, this article employed one of MADM methods namely TOPSIS (the technique for order of preference by similarity to ideal solution) to solve the proposed model. In order to validate and verify the proposed algorithm, the SAW (simple additive weighting) was used as well. The main contribution of this paper was to consider two criteria namely the availability of materials and the payment methods. In order to present the performance of the proposed strategy, the considered problem was implemented in a manufacturing company in which the best supplier was selected. As the future research, determining the criteria weights can be considered by analytical network process (ANP) method.

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